# Financing the Green Deal: carbon tax and green finance in a Stock-Flow Consistent behavioural model

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# Issues at stake for the EU zero-carbon transition

- **Need to scale up green public and private investments** to achieve the EU climate targets (1 trillion in sustainable investments by 2030)
- **Markets are not pricing climate risk**: challenges to fill the green investment gap and preserve financial stability (Monasterolo and de Angelis 2020)
- **Carbon pricing** advocated to signal the market but insufficient (Stiglitz 2019). Need to pay attention to potential trade-offs btw eco-envir-social objectives (von der Leyen 2019)
- **Complexity** of transition towards sustainable economy and finance requires to exploit synergies across policies (von der Leyen 2019)
- **Knowledge gap**: models needed to analyse the interplay between climate policies, socio-economic and financial impacts

# 3 research questions

- How could a EU country foster a **just carbon free transition**, i.e. Green Deal?
- To what extent **carbon tax and green sov. bonds** financing could endogenously trigger the **green investments** needed?
- Under which conditions could **trade-offs and unintended effects** on macroeconomic performance, financial stability, inequality emerge?

# Climate transition risk: endogeneity and complexity

- Climate transition risk (stemming from a disorderly transition) is endogenous, complex and non-linear.
- This means that the feasibility of making the transition depends on the risk perception of agents (gov and investors).
  - Agents are uncertainty about the equilibrium that will prevail, and thus cannot have perfect foresight We can have **multiple equilibria**
- One (optimal) policy (i.e carbon pricing) is not enough ( Stiglitz 2019)
- Thus, to analyse climate transition challenges, we need models that allow to depart from one single equilibrium and optimal policy, and **embed complexity and non-linearity**.

# State of the art

- **Climate Stress-test**: Investors' exposures to climate transition risk is large and amplified by network effects (Battiston et al. 2017).
- Criticism to climate economic models **(fat tails, endogeneity, discounting)** (Pindyck, 2013; Weitzman 2009, Stern 2013)
- **Stock-Flow Consistent (SFC) modelling** (Godley and Lavoie, 2012) introduced a realistic representation of money and finance
- **SFC-behavioral models**: contribution to macroecological modeling and policy analysis by combining advantanges of SFC and ABM:
  - Command and control policies: Lamperti ea. 2018
  - Green fiscal and monetary policies: Bovari ea. 2018, Dafermos ea. 2018, Monasterolo and Raberto 2018, Ponta ea. 2018
  - Prudential regulation: Dunz ea. 2019, Raberto ea. 2019

# Contributions of the EIRIN model

- EIRIN provides a framework to analyse the **interplay of public policy, economy and finance** in the low-carbon transition
- Eirin is a SFC-AB macroeconomic model with **heterogeneous agents/sectors** (parsimonious in complexity):
  - Households (capitalist/worker, Goodwin 1967): income source, wealth, access to finance, saving/consumption (Deaton's buffer-stock theory)
  - Capital goods (green/brown) based on emissions and resource intensity
  - Energy producers (utilities brown/green, energy fossil)
- **Behavioral rules** based on experimental, evolutionary economics
- **Endogenously generated behaviours** and out-of-equilibrium dynamics analysed via computer simulation and sensitivity analysis

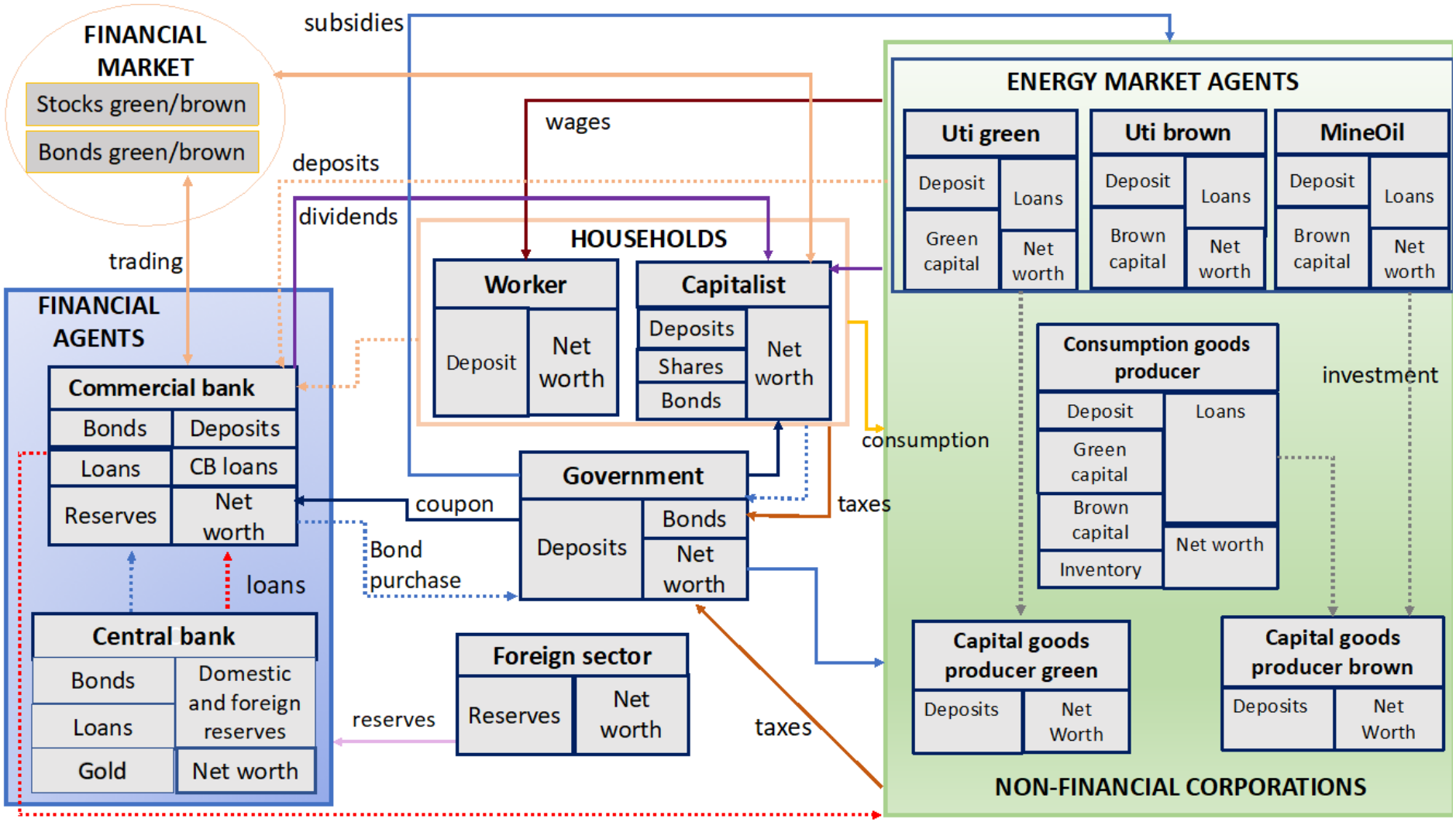
# SFC Agent-Based modelling characteristics

- **Represents agents as a network of interconnected balance sheets**: allows to increase transparency wrt to drivers of shocks transmissions and impacts for better policy evaluation
- **Departs from equilibrium conditions** and from strong assumptions on agents' rationality and representativeness, perfect markets
- **Provides a rigorous accounting framework**: equilibrium conditions substituted by accounting identities that hold irrespective of any behavioral assumption
- Allows to discover **emerging** (often unexpected) micro-based macroeconomic dynamics and track **causal transmission channels**

# EIRIN added value to traditional macroeconomic models

- **Endogenous GDP growth and money creation** to support investments (Post-Keynesian, demand driven)
- **Market power** (mark up pricing on unit cost): no market clearing and no perfect competition
- **Deep uncertainty** on the future translates in adaptive expectations of agents: no optimal foresight
- **Portfolio choices** of firms, households and investors drive distributive effects (differentiated access to gains on markets)
- Conditions for public policies to **crowd in** green investments

# EIRIN structure: main capital (dot)/current account flows



# Sequence of events

1. **Policy makers** (Gov., central bank) adjust mon. policy and tax rates according to inflation, deficit, emissions targets.
2. **Production/investment/consumption plans** are made
3. **Credit market opens**. If bank's credit supply is lower than demand then production plans are revised downward by borrowers
4. **Real markets open in parallel**. Mark-up pricing applied by suppliers. Transactions occur at **disequilibrium** (non-linearities, time delay)
5. **The financial market opens**. Gov. issues new brown (green) bonds to finance budget deficit (green subsidies). Investors make portfolio decisions (green/brown equity, bonds). New asset prices determined.
6. All transactions and monetary flows are recorded and **agents/sectors' balance sheets updated**.

# Green subsidies decrease costs of renewable investments

Green utility company $U_g$ makes investment decisions in renewable energy capacity based on Net Present Value rule:

$$NPV = -(1-\gamma)p_{K_g} q_{K_g}^{U_g} + \frac{p_e \, \epsilon_e \, q_{K_g}^{U_g}}{r_D}$$

- $\gamma$: share of investment cost financed by government (green subsidy)
- $p_e$: electricity/energy price
- $r_D$: discount rate of future cash flows
- $q_{K_g}^{U_g}$: investment in green capital goods (e.g. solar panels)
- $p_{K_g}$: price of green capital goods
- $\epsilon_e$: energy efficiency of green capital goods (parameter)

- **Magnitude** of green investment is endogenously generated (emerging behaviour) but **timing** is influenced by policy and market conditions

# Asset allocation and asset pricing model

- Nine assets classes: **7 equity stocks and 2 gov bonds** (brown/green).
- **Asset prices** set as **equilibrium prices** as the **ratio** between the aggregate financial wealth allocated by market players to each class and the number of class' outstanding shares.
- **Portfolio allocation** depends on the **relative capitalization** of each asset class evaluated considering so-called "rational" (fundamental) prices (not current market prices)
- "Rational" (fundamental) prices determined according to the **discounted cash flow model** (Gordon 1959)

# Rational (fundamental) asset prices

- $\hat{p}^s_{E_a}$ (**expected rational equity price**)

$$\hat{p}^s_{E_a} = \frac{\hat{d}^s_a}{r^s_{E_a} - \hat{g}^s_a} \qquad a \in \{C, K_b, K_g, mi, U_b, U_g, BA\},$$

  - $\hat{d}^s_a$: expected next step dividend (**adaptive expectations**)
  - $\hat{g}^s_a$: expected dividends's growth rate (**adaptive expectations**)
  - $\hat{r}^s_{E_a}$: CB's policy rate plus a given **risk premium** $\delta$, **higher when investors react to the carbon tax** (climate sentiments).

- $\hat{p}^s_{B_a}$ (**expected rational bond price**) (infinitely-lived bonds)

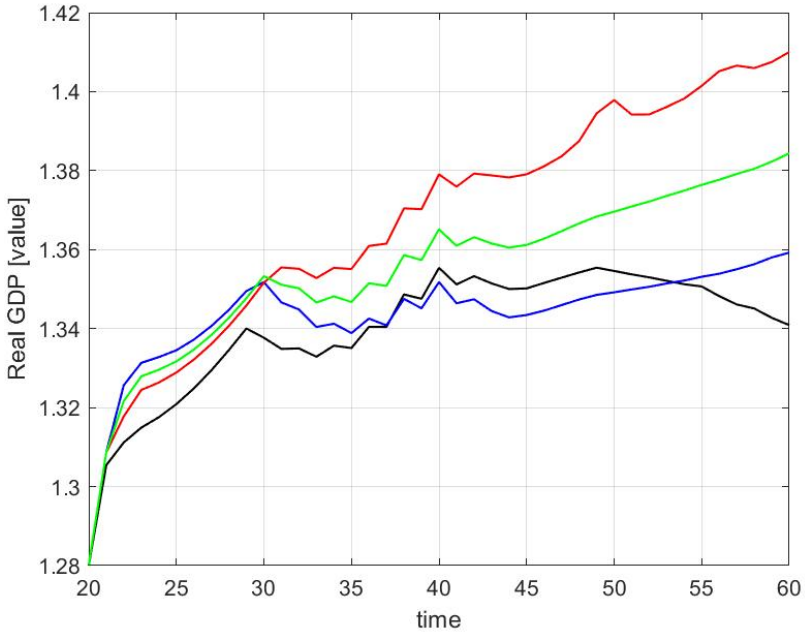
$$\hat{p}^s_{B_a} = \frac{c}{r^s_a} \qquad a \in \{b, g\},$$

  - $c$: (known and fixed) coupon equal for brown and green
  - $\hat{r}^s_a$: discount rate set as CB's policy rate plus a premium

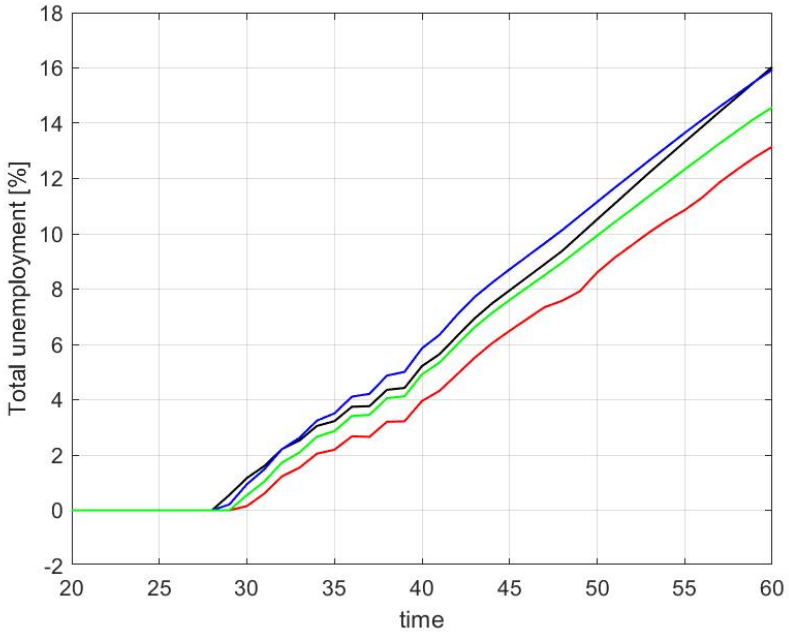
# Policy scenarios

- We simulate **three scenarios** characterised by different financing of green subsidies to allow the country to achieve the emissions reduction targets
  - **Carbon tax** (with reinvestment of revenues in green subsidy) (Stiglitz ea 2017, IMF 2019) (blue)
  - **Green sovereign bonds** conditioned to green energy investments (red)
  - **Policy coordination**: green sov. bonds and carbon tax (green)
  - **Business as Usual (BAU)**: no policy (black)

# Green bonds (carbon tax) improve (decreases) macroeconomic performance

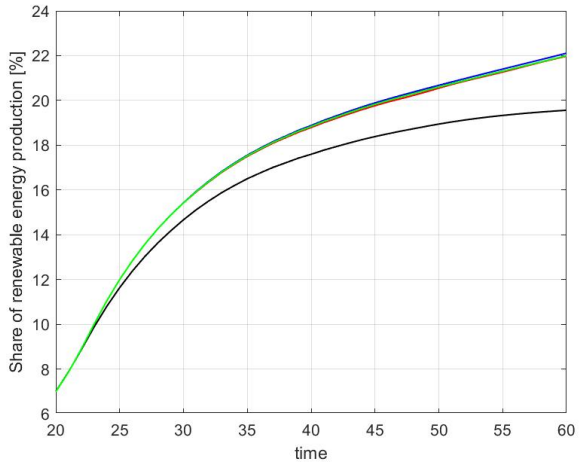



(a) Real GDP

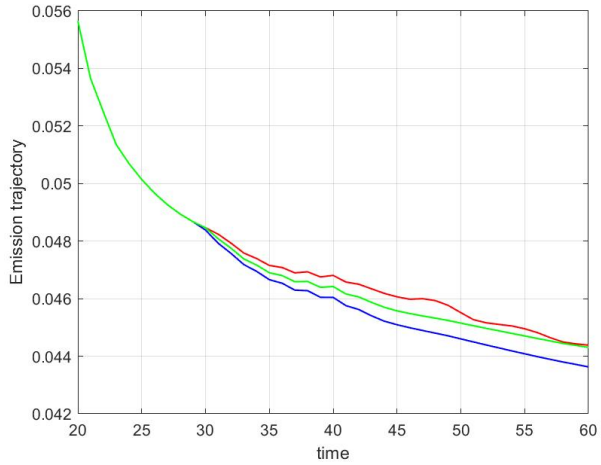



(b) Unemployment Rate

# Policies stimulate renewable energy production and emissions reduction but differences across instruments



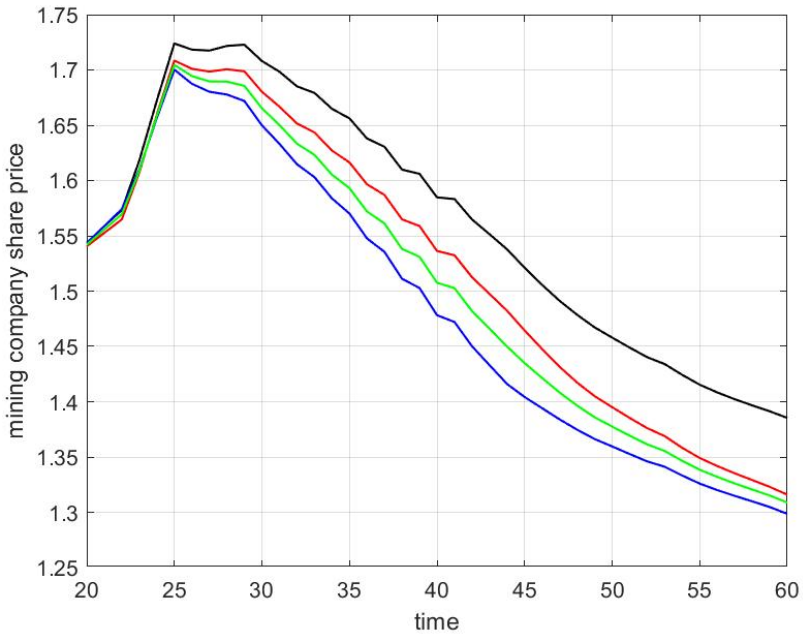

(c) Renewable Energy Share



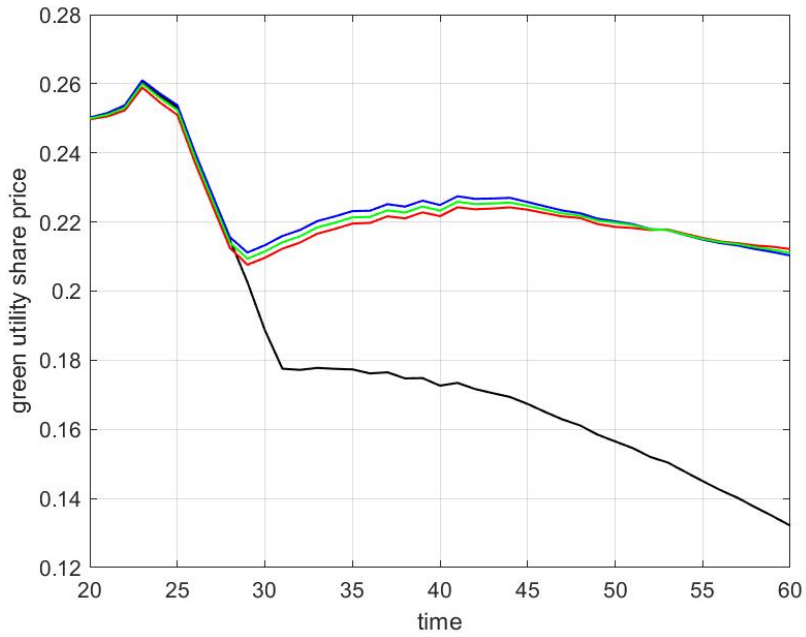

(d) Total emissions

- Renewable energy share increases as reaction to policies (vs BAU)
- Emissions decrease the most in carbon tax scenario due worse economic performance (higher brown firms' costs and thus lower investments and GDP growth, higher inflation)

# Stock market prices reflect (worse) brown/(better) green firms' performance



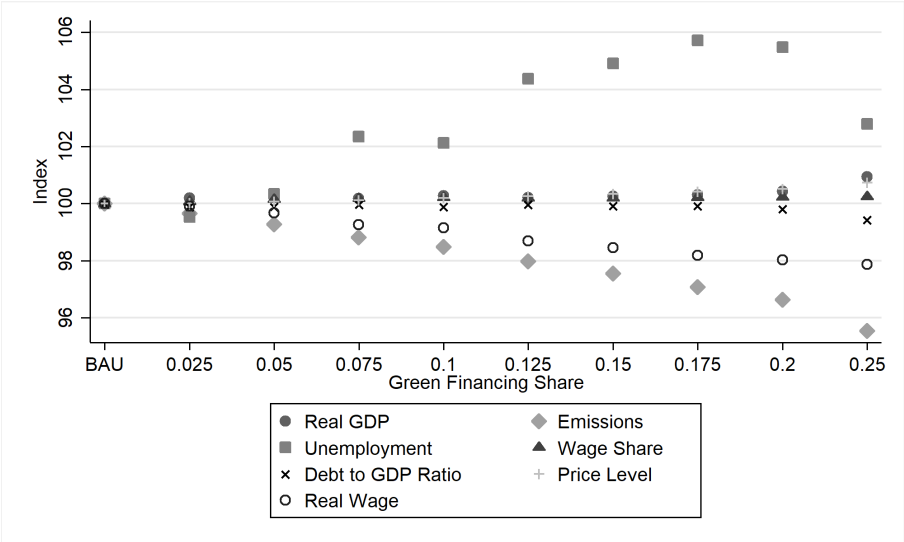

(e) Mining Company



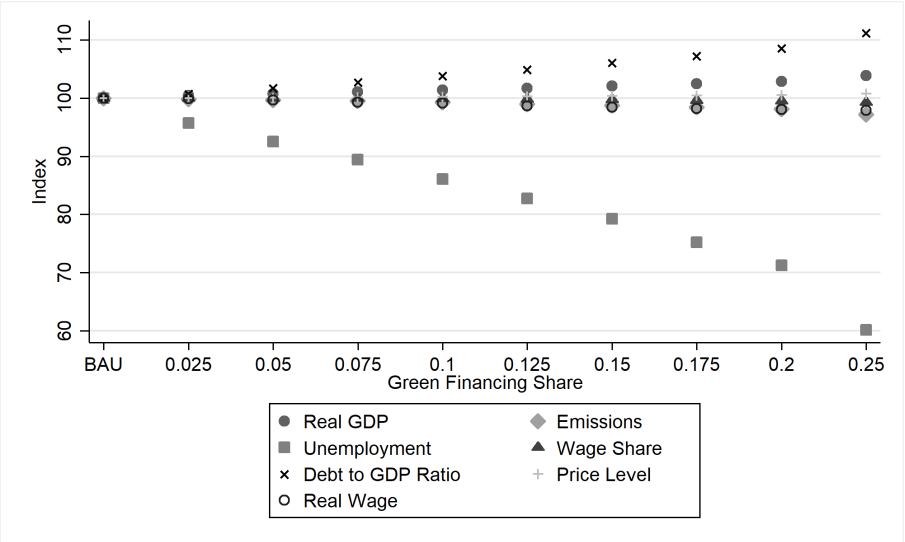

(f) Green utility company

- Policies induce a shift from brown to green with positive (negative) effects for green utility (mining company) stock prices
- Mining company's stock prices the lowest in carbon tax scenario due to tax costs.

# Comparing Green Bonds and Carbon Tax



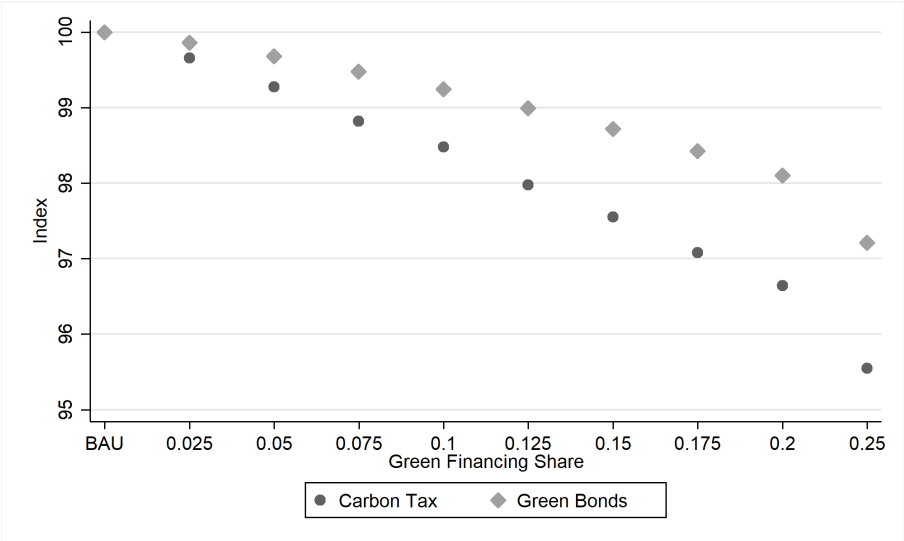

(g) Carbon Tax Scenarios



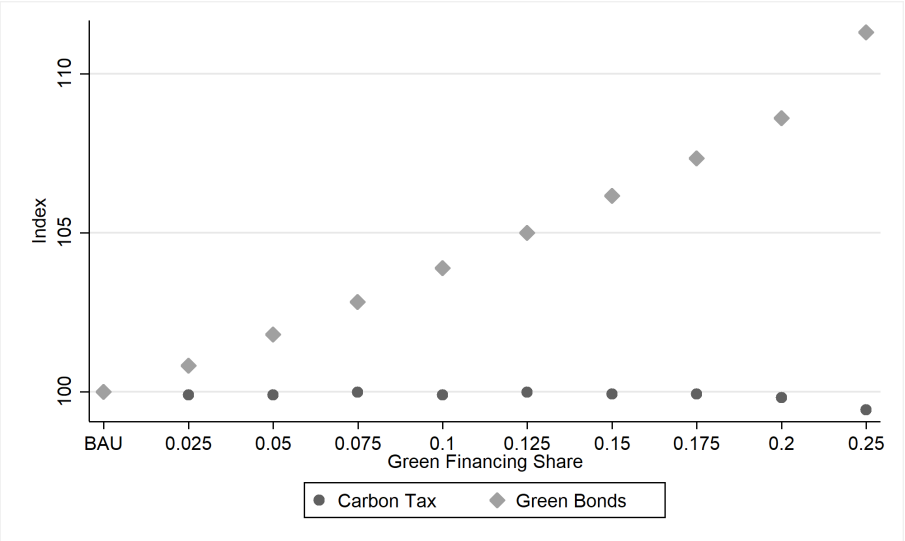

(h) Green Bonds Scenarios

- Carbon Tax trade-off: emissions decrease (lower brown investments, GDP, real wage) and budget neutral (debt to GDP) but higher unemployment and prices (mark-up).
- Green Bond: green multiplier effect (investments, GDP and thus employment). High capitalist income from higher bond yields. But no budget neutral (higher debt to GDP ratio); emission reduction effect partly offset by GDP stimulation.

# Green Bonds vs. Carbon Tax: macroeconomic performance

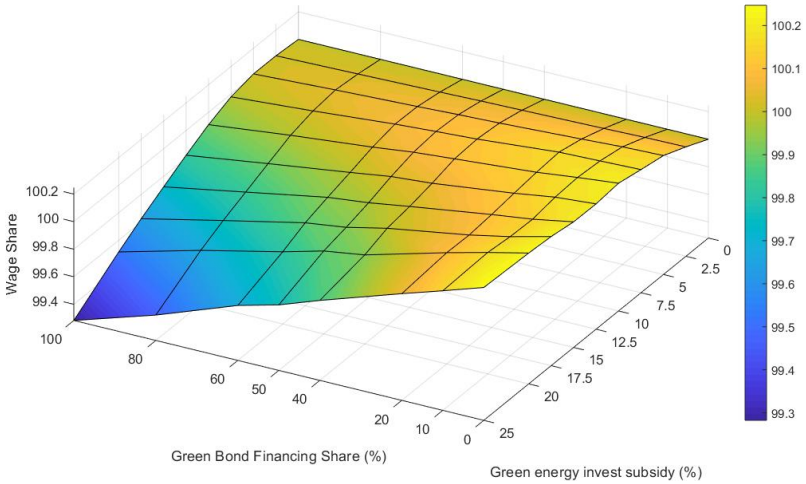



(i) Mean CO2 Emissions

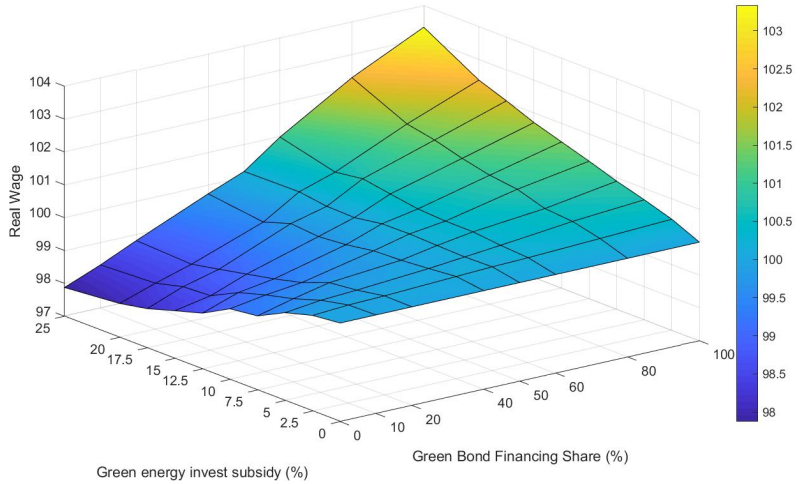



(j) Mean Debt to GDP

# Policy mix: non-linear distributive effects




(k) Mean Wage Share




(l) Mean Real Wage

- Wage share increases with high carbon tax share: lower brown firms' profits and stock prices reduce capitalists income
- Wage share decreases with high green bonds share: positive effect on GDP and bond yields (issuance/price) drives capitalists' profits
- Wages increase w.high green bond share (better GDP, workers wage bargain)/decreases w.high carbon tax share (inflation, unemployment)

# Conclusions

- Government policies could **signal** investors' portfolio choices in economy and finance and foster the transition (towards a Green Deal)
- But **magnitude** of macroeconomic (GDP, inflation) and distributive effects (wage share), emissions reduction depends on type of financing (carbon tax/green bonds/mix)
- Green finance instrument have different **financial and distributive effects** (e.g. public debt/GDP): **synergies** across instruments could help mitigate **trade-offs**
- New Klimafond **GreenFin** project explores synergies across green fiscal, monetary policies and financial regulations in EU: focus on structured and development finance (EIB)